

This Page Is Inserted by IFW Operations  
and is not a part of the Official Record

## **BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning documents *will not* correct images,  
please do not report the images to the  
Image Problem Mailbox.**

# (12) UK Patent Application (19) GB (11) 2 255 033 (13) A

(43) Date of A publication 28.10.1992

(21) Application No 9208894.7

(22) Date of filing 24.04.1992

(30) Priority data  
(31) 690704

(32) 24.04.1991

(33) US

(71) Applicant  
Baker Hughes Incorporated

(Incorporated in the USA - Delaware)

3900 Essex Lane, Suite 1200, Houston,  
Texas 77027, United States of America

(72) Inventor  
Ketankumar K Sheth

(74) Agent and/or Address for Service  
Edward Evans & Co  
Chancery House, 53-64 Chancery Lane, London,  
WC2A 1SD, United Kingdom

(51) INT CL<sup>5</sup>  
B04B 11/02 5/00 5/12

(52) UK CL (Edition K)  
B2P P10C3B3 P10C3D P10C3F P6X P8A  
U1S S1269 S1748 S2005 S2316

(56) Documents cited  
GB 2124929 A GB 1559547 A

(58) Field of search  
UK CL (Edition K) B2P  
INT CL<sup>5</sup> B04B  
Online databases: WPI

## (54) Gas separator

(57) A gas separator for an electric submersible centrifugal pump for a well separates gas from liquid components eg water, oil of the well fluid. The gas separator has a rotatably driven rotor 27. The rotor has an outer cylinder 29, an inner hub 31 and one or more longitudinal vanes 33 that extend between the inner hub and outer cylinder. Notches 35 are formed in the upper edge of the vanes. A stationary discharge member 37, mounted above the rotor, has a depending skirt 39 that extends into the notches. This defines a separate inner flow path 41, 45, 53, 47 for gas to flow out of the separator into the well. The unseparated portions (liquid) of the well fluid flow in a clearance 43 between the skirt and the housing into a second separator stage and then into a pump intake. Supports 49 extend radially out from the discharge member for securing the discharge member in the housing, e.g. by a screw 55.

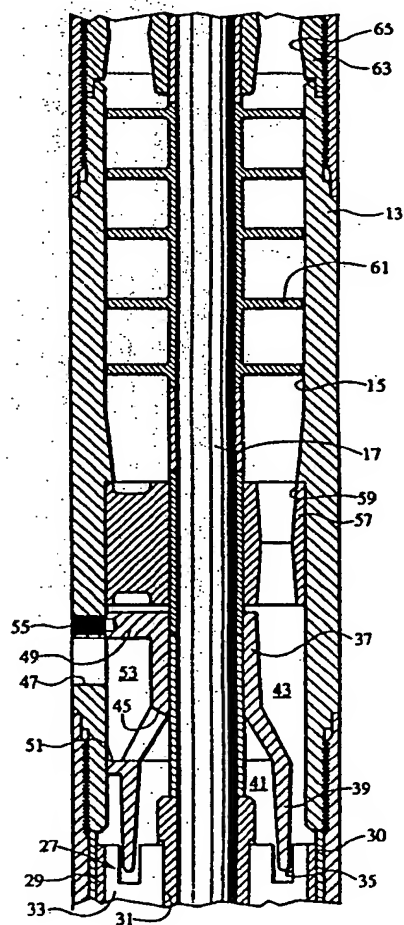


Fig. 1B

GB 2 255 033 A

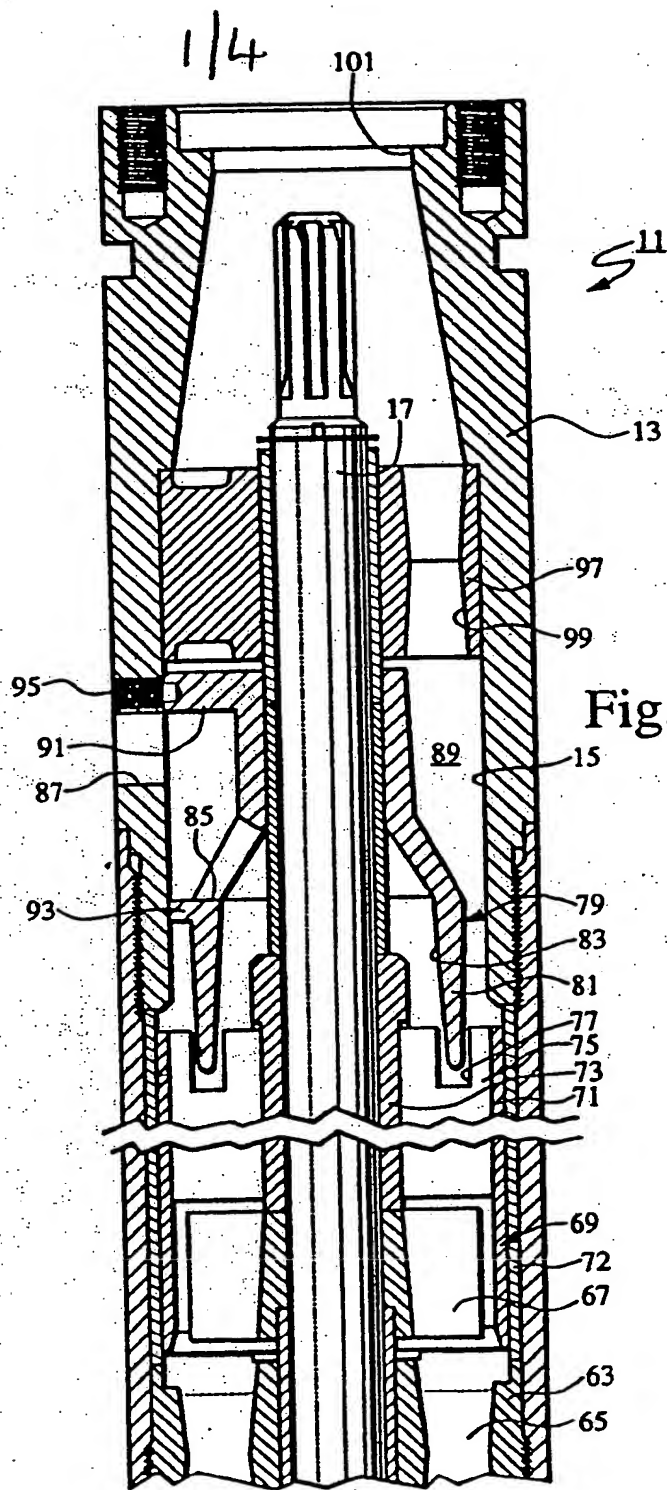


Fig.1A

2/4

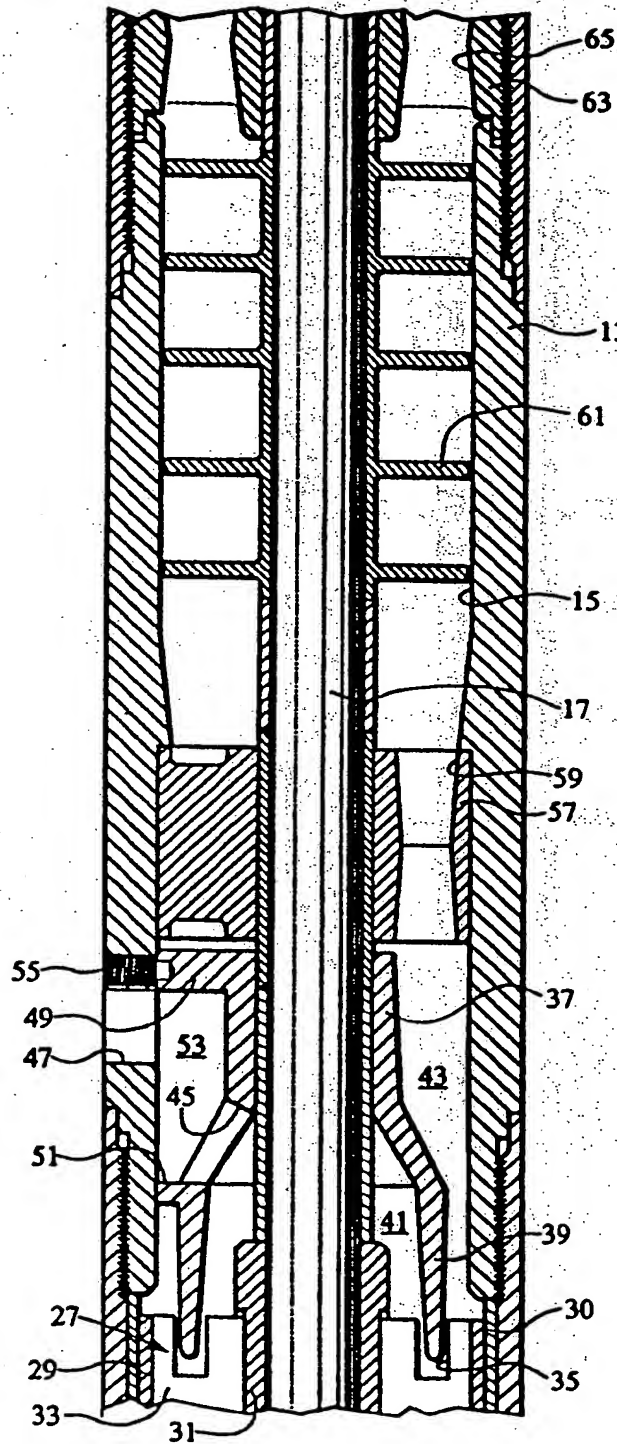


Fig. 1B

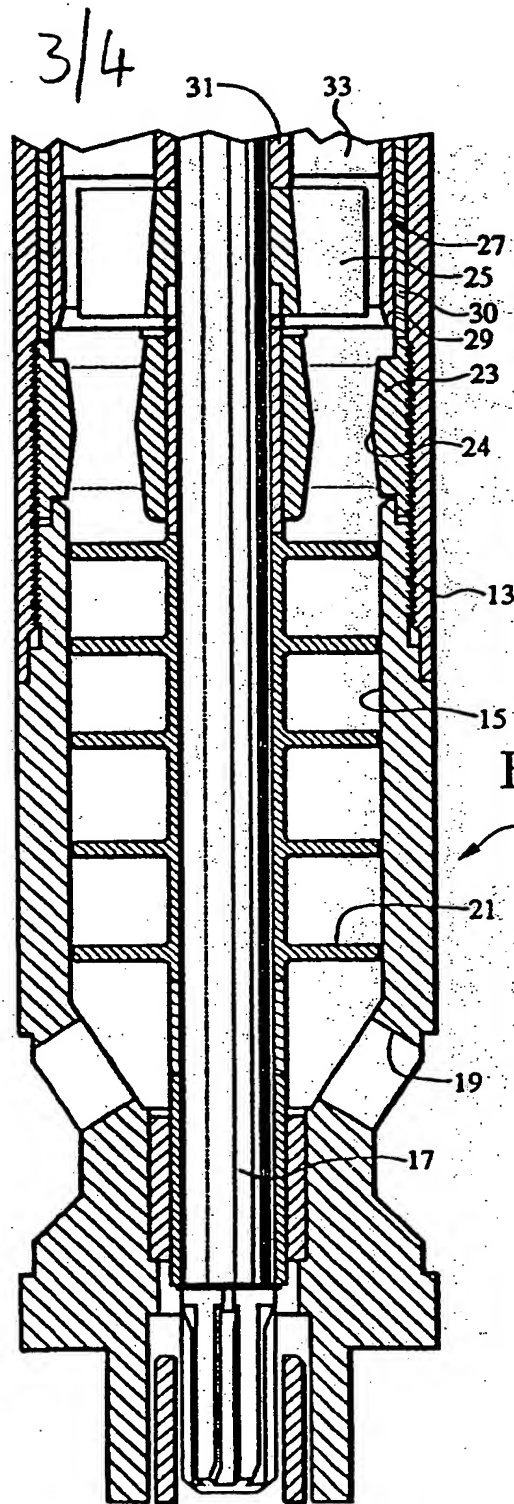
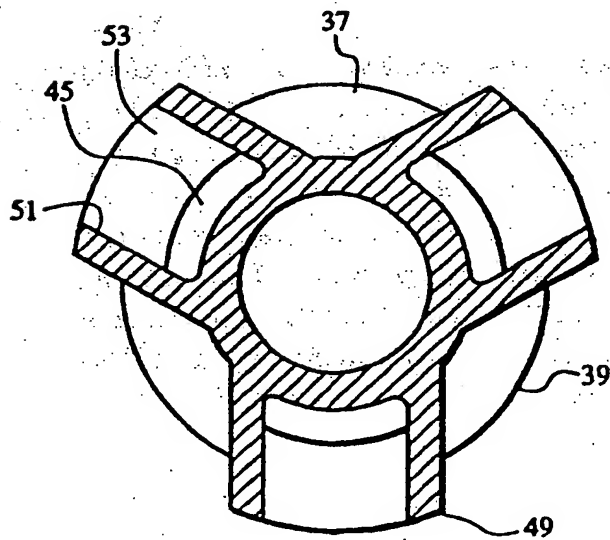
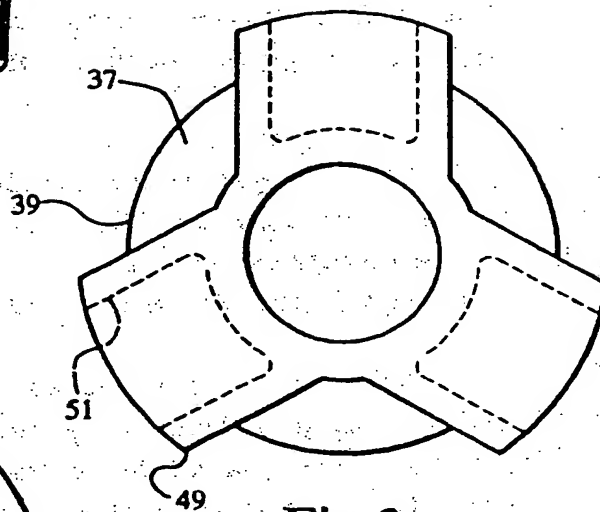
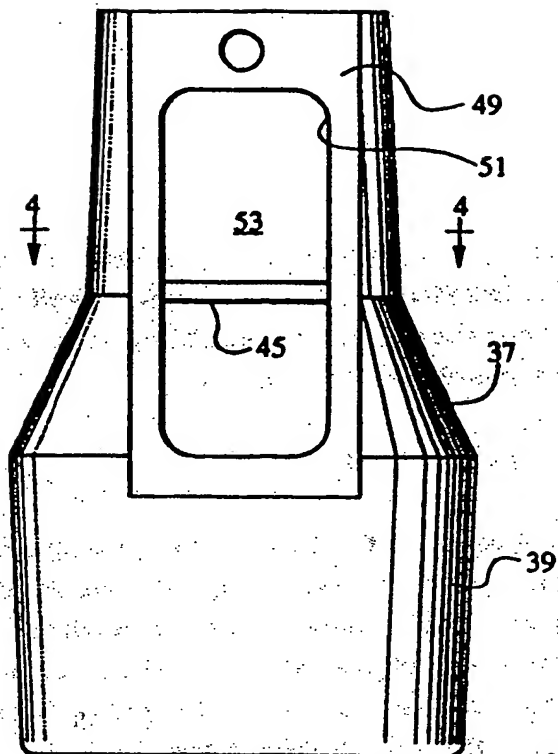


Fig. 1C



- 1 -

This invention relates in general to electrically driven centrifugal submersible well pumps, and in particular to a gas separator for separating gas from the well fluid prior to reaching the pump.

2. Description of the Prior Art:

Submersible well pumps of the type concerned herein are centrifugal and driven by a downhole electrical motor. A pump will have a large number of stages, each stage having an impeller rotatably driven within a diffuser. These pumps are used to pump large volumes of fluid, such as oil and water from wells.

Most oil wells typically will also produce some gas. If the gas is of sufficient volume, it can reduce the performance of the pump. In these circumstances, gas separators are mounted in the assembly below the pump and above the motor and the mechanical seal.

Prior art gas separators utilize a rotatably driven rotor within a cylindrical housing. The rotor has at least one blade or vane. The vane will impart a centrifugal force to the well fluid flowing through the housing. This centrifugal force tends to separate the liquid components from the gas components because of difference in densities, with the liquid components locating near the outer wall of the housing, and the gas remaining near the shaft.

A discharge member is mounted above the rotor. The discharge member provides a passage from the central portion of the rotor to the exterior of the gas separator to discharge gas. The discharge member also provides a liquid passageway for the remaining portion of the well fluid to flow upward toward the intake of a pump.

Although the above-described apparatus is workable, improvements are desirable, as are provided by the present invention as defined in claim 1.

An example of the invention will now be described with reference to the accompanying drawings, in which:-

Figures 1A, 1B and 1C show sectional views of a gas separator,

Figure 2 is a side view of the discharge member used in the gas separator of Figure 1, showing a side 90 degrees from the position shown in Figure 1,

Figure 3 is a plan of the discharge member of Figure 2 and

Figure 4 is a sectional view of the discharge member of Figure 2 taken along the line IV-IV of Figure 2.



Referring to the drawings, and in particular to Figure 1C, gas separator 11 has a cylindrical housing 13. Housing 13 has an axial inner passage 15. A shaft 17 extends through the passage 15. Shaft 17 will be driven by a motor (not shown) mounted below the gas separator 11 and separated by a seal section (not shown). An inlet 19 locates in the bottom of housing 13 for drawing well fluid into passage 15.

The well fluid proceeds first to an inducer 21. Inducer 21 comprises a helical screw mounted to the shaft 17 for rotation with it. Inducer 21 conveys the fluid upward and pressurizes the fluid to prevent expansion of the gas contained in the fluid at that point.

The well fluid then passes through a bearing 23, which is of a spider type, having a plurality of passages 24. The well fluid proceeds to a set of guide vanes 25. Guide vanes 25 are mounted to the shaft 17 for rotation therewith. Preferably there are more than one of the guide vanes 25, each comprising a flat or curved plate, and each being inclined relative to the axis of shaft 17. Guide vanes 25 impart a swirling motion to the well fluid.

Guide vanes 25 are located in the lower portion of a rotor 27. Rotor 27 has an outer cylinder 29 which extends down over guide vanes 25. Outer cylinder 29 encloses an inner hub 31 and is closely spaced within a stationary sleeve 30 mounted in the passage 15. Inner

hub 31 mounts to the shaft 17 for rotation with the shaft 17. Two or more rotor vanes 33 (only two shown) extend between the hub 31 and the outer cylinder 29. Vanes 33 comprise longitudinal blades extending from the lower end to the upper end of the rotor 27. Each vane 33 is located in a radial plane of the axis of shaft 17. Each vane 33 is vertically oriented.

Referring to Figure 1B, each vane 33 preferably has a notch 35 formed in its upper end. Notch 35 is a longitudinal slot that extends downward a short distance from the upper edge of each vane 33. In the embodiment shown, each notch 35 is located approximately midway between the hub 31 and the outer cylinder 29. The notches 35 also may be positioned to one side or the other of the midpoint between hub 31 and outer cylinder 29, depending on the amount of separation desired. The rotor 27 imparts a centrifugal force to the well fluid, causing heavier liquid components to flow outward toward the outer cylinder 29 as they progress up the rotor 27. The lighter gaseous phase will remain in the central portion of the rotor 27, near the hub 31.

A discharge member 37 mounts stationarily directly above rotor 27. Discharge member 37 does not rotate with shaft 17. Discharge member 37 has a depending skirt 39 that extends downward. Skirt 39 is concentric with shaft 17. Skirt 39 is annular, having an outer diameter significantly smaller than the inner diameter of the passage 15 of housing 13. The inner diameter of skirt 39 is significantly greater than the outer

diameter of inner hub 31. This results in an annular gas cavity 41 located within skirt 39.

The clearance between the skirt 39 and the passage 15 comprises a liquid passage 43. The portion of the well fluid that does not enter gas cavity 41 will flow up through the liquid passage 43. A plurality of gas passages 45 (only one shown in Fig. 1B) extend through discharge member 37. In the embodiment shown, there are three of the gas passages 45, and each communicates with a gas outlet 47 extending through housing 13. Gas outlets 47 allow separated gas to be discharged into the well.

As shown also in Figures 3 and 4, discharge member 37 has a plurality of laterally extending supports 49. In the embodiment shown, there are three supports 49 spaced 120 degrees apart from each other. The supports 49 extend out into contact with the passage 15. Each support 49 has a generally rectangular perimeter, having flat upper and lower edges and side edges, as shown in Figure 2. The outer face of each support 49 is a segment of a cylinder having approximately the same diameter as the inner diameter of passage 15. The outer face of each support 49 extends circumferentially about 45 degrees.

The well fluid in the liquid passage 43 flows between the supports 49. A window 51, which is rectangular in the embodiment shown, is located in the outer face of each support 49. Window 51 registers with one of the gas outlets 47 (Fig. 1) and communicates with a cavity 53 defined by the interior

of each support 49. Window 51 and cavity 53 may be considered a part of the gas passage 45 leading to a gas outlet 47 (Fig. 1). A fastener, screw 55, or locking device extends through a hole in housing 13. The tip of screw 55 engages a dimple provided in one of the upper supports 49. This engagement prevents rotation of the discharge member 37 and also fixes the discharge member 37 axially.

Referring still to Figure 1B, a bearing 57 mounts in housing 13 directly above discharge member 37. Bearing 57 has a plurality of axial passages 59 extending through it.

In the embodiment shown, the gas separator 11 is of a tandem type, and can have two or more units joined in series depending upon well conditions. That is, there are two separate and independent separator portions. The structure of the separator portion above bearing 57 is the same as that below. This structure includes an inducer 61. A bearing 63 locates above inducer 61. The well fluid passing through liquid passage 43 may still contain some gas. The well fluid flows through passages 65 in bearing 63 to an upper guide vane 67. Upper guide vane 67 rotates with shaft 17.

Upper guide vane 67 locates in the lower portion of an upper rotor 69. Rotor 69 has an outer cylinder 71 closely spaced to a stationary sleeve 72 in housing 13. An inner hub 73 mounts to shaft 17 for rotation with shaft 17. A plurality of longitudinal vanes 75

extend between inner hub 73 and outer cylinder 71. Each vane has a notch 77 in its upper edge.

An upper discharge member 79 mounts stationarily above upper rotor 69. Upper discharge member 79 has a depending skirt 81, the lower edge of which extends into the notches 77. Skirt 81 defines a gas cavity 83 on its inner diameter. Three gas passages 85 lead through the upper discharge member 79, each to an upper gas outlet 87. Liquid passage 89 is located in a clearance between the skirt 81 and the inner diameter of housing 13.

The upper discharge member 79 has three supports 91, each having a window 93. The supports 91 extend to the inner diameter of housing 13 and are circumferentially spaced apart from each other. A fastener 95 extends through a threaded hole in housing 13 and has an inner end that engages the support 91.

A bearing 97 mounts in housing 13 above upper discharge member 79 for supporting shaft 17. Bearing 97 has one or more axial passages 99 for the flow of well fluid. The well fluid flows through a bore outlet 101 on the upper end into the intake of a pump (not shown).

In operation, the well fluid flows in intake 19 (Fig. 1C). The inducer 21 will apply pressure to the well fluid, which then flows through guide vanes 25 into rotor 27. The spinning rotor 27 causes some separation of the gas and liquid, with the heavier

liquid components moving outward toward the outer cylinder 29.

Referring to Figure 1B, the gaseous phase remains near inner hub 31 and will flow through the gas cavity 41, gas passage 45 and out the gas outlet 47. The remaining portion of the well fluid, which may be a mixture of liquid and gas, will flow up the liquid passage 43 and through the bearing passage 59.

The well fluid at that point enters a second separation stage which operates in the same manner as previously described. The well fluid is pressurized again by an inducer 61. The well fluid flows into rotor 69 (Fig. 1A). Again, separation occurs. The separated gas flows through gas cavity 83, gas passage 85 and out gas outlet 87. The remaining well fluid flows up the liquid passage 89, through the passage 99 and out the bore outlet 101. The well fluid then enters the intake of a pump (not shown).

The invention has significant advantages. Utilizing a stationary skirt with the diffuser enhances separation of the liquid and gaseous components. The stationary skirt is less expensive to manufacture than a rotating skirt such as used in one prior art type of gas separator. The discharge members are easier to install as they are held by fasteners rather than by axial compression as in one prior art type.

# CLAIMS

1. A gas separator for a submersible centrifugal pump for a well, the gas separator having a cylindrical housing with a bore extending therethrough, a shaft driven by a motor of the pump and extending axially through the bore, an intake in the lower end of the housing for receiving well fluid containing liquid and gas, a rotor mounted on the shaft for rotation therewith for receiving fluid flowing through the bore of the housing and forcing the liquid phase radially outward while the gas phase flows through a central portion of the rotor, the rotor having an inner hub, at least one longitudinal vane extending radially outward from the inner hub, and a discharge member mounted stationarily above the rotor for directing the gas outward into the well and directing the liquid upward into an intake of the pump, an annular stationary skirt on the discharge member extending downward toward the rotor radially outward of the shaft and radially inward of the bore of the housing, the interior of the skirt defining a gas cavity for discharging gas through a gas outlet in the housing into the well, a plurality of circumferentially spaced apart supports, each extending radially outward from the discharge member into contact with the bore of the housing, and a fastener extending through a wall of the housing into engagement with one of the supports for securing the discharge member within the housing.

2. A gas separator as claimed in claim 1 wherein the supports are located above the skirt and located such that the portion of the wall fluid that does not flow into the

gas cavity flows between the supports.

3. A gas separator as claimed in claim 1 or claim 2 wherein each of the supports contains gas passage means for communicating from the gas cavity to the gas outlet.

4. A gas separator as claimed in any one of claims 1 to 3 wherein the skirt on the discharge means extends downward into the rotor radially outward of the hub and radially inward of the outer periphery of the rotor.

5. A gas separator as claimed in any one of the preceding claims comprising a notch formed in an upper edge of the vane for receiving a lower edge of the skirt.

6. A gas separator as claimed in any one of the preceding claims wherein there are three of the supports, spaced 120 degrees from each other.

7. A gas separator substantially as herein described with reference to the accompanying drawings.



- 11 -

Patents Act 1977

Examiner's report to the Comptroller under  
Section 17 (The Search Report)

Application number

9208894.7

Relevant Technical fields

- (i) UK CI (Edition K) B2P
- (ii) Int CL (Edition 5) B04B

Search Examiner

R E SHOEFIELD

Databases (see over)

- (i) UK Patent Office
- (ii) ONLINE DATABASES: WPI

Date of Search

17 JULY 1992

Documents considered relevant following a search in respect of claims

1-7

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	GB 2124929 A (TRW INC) See especially page 3 lines 44-48	1-3
X	GB 1559547 (BORG-WARNER)	1-4

Category	Identity of document and relevant passages	Relevant to claim(s)

#### Categories of documents

**X:** Document indicating lack of novelty or of inventive step.

**Y:** Document indicating lack of inventive step if combined with one or more other documents of the same category.

**A:** Document indicating technological background and/or state of the art.

**P:** Document published on or after the declared priority date but before the filing date of the present application.

**E:** Patent document published on or after, but with priority date earlier than, the filing date of the present application.

**&:** Member of the same patent family, corresponding document.

**Databases:** The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).